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APPLICATION NOTE

POLARIZATION MODULATION TECHNOLOGIES

Polarimetry: Optical Rotation

by Dr. Theodore Oakberg

When linear polarized light passes through an "optically active" material, a rotation of the plane of polarization of the light may occur. This phenomenon is called Optical Rotation. Measurement of optical rotation of a sample is called "Polarimetry" by chemists.[1] Optically active materials include chiral organic molecules such as dextrose and crystals with asymmetric structures such as quartz.

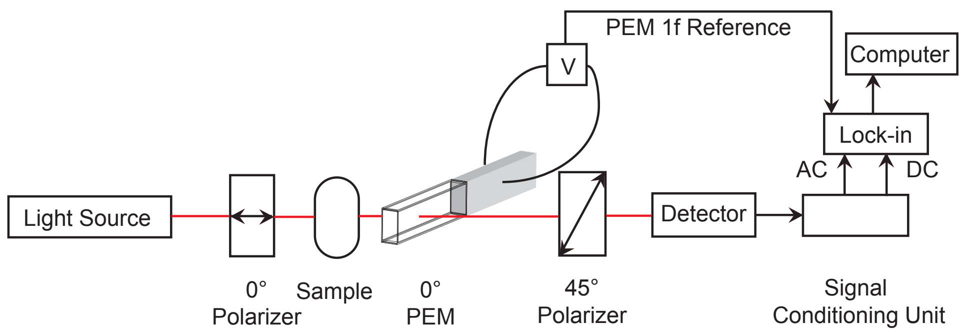

Figure 1. Optical bench setup for measurement of optical rotation

One simple setup for measuring optical rotation is shown in Figure 1. If the light source is a laser, the optical setup is particularly simple since no collimating and focusing lenses are required. The first polarizer after the light source should be mounted in a precision rotator to allow precise alignment with the PEM retardation axis. For this configuration (with no sample in place) there is no AC signal at the detector but there is a DC signal. When a sample is inserted and a rotation occurs, a signal at twice the PEM frequency (2f) will appear at the detector. The signal at the detector may be expressed as a Fourier series according to Equation 1.

$$I(t) = \frac{1}{2}[1-J_0(A)\sin\alpha + 2J_2(A)\cos(2\pi ft)\sin(\alpha) + higher\_terms] \qquad (1)$$

where α = optical rotation, degrees or radians

A = PEM peak retardation, radians

f = PEM frequency,

J_0 and J_2 are Bessel functions of the PEM retardation A

The first two terms in the square brackets are the "DC" term and the third term is the "AC" term which is at 2f, twice the PEM frequency. V_0 or the DC term is given by Equation 2.

$$V_{DC} = \frac{K}{2}[1-J_0(A)\sin\alpha] \qquad (2)$$

where K is an experimental constant of proportionality.

[1] Another measurement process called "Polarimetry" is Stokes polarimetry which is concerned with the measurement of all the polarization characteristics (Stokes parameters) of a light source and requires a more complex experimental setup.

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V_{2f}, the amplitude of the AC signal at 2f is given by Equation 3

$$V_{2f} = KJ_2(A)\sin\alpha \tag{3}$$

where K is the same experimental constant that is in Equation 2.

For an optimum setup, the PEM retardation is chosen to be A = 0.383 waves = 2.405 radians. For this retardation, $J_0(A) = 0$ and the DC term is independent of the optical rotation.

It is also convenient to compute the ratio of V_{2f}/V_{DC}. (Equation 4)

$$R_{2f} = \frac{V_{2f}}{V_{DC}} \tag{4}$$

R2f is insensitive to fluctuations in the light source, changes in optical transmission, etc.

The signal conditioner derives both an AC signal and a DC signal from the detector output. The lock-in amplifier measuresV_{2f} (rms) and many lock-ins can sense VDC. The computer reads both values through the RS232 interface with the lock-in. The optical rotation α is given by Equation 5.

$$\alpha(radians) = \sin^{-1}\left[\frac{\sqrt{2}R_{2f}}{2J_2(A)}\right] \tag{5}$$

The factor √2 in the numerator converts the lock-in rms voltage to peak voltage. For A = 2.405 radians, $J_2 = 0.4318$. Putting numerical values in and converting the expression to degrees, a practical formula for α is given in Equation 6.

$$\alpha(degrees) = 57.3\sin^{-1}[1.638R_{2f}] \tag{6}$$

For small angles (α </= 15°) the optical rotation in degrees is given by Equation 7, accurate to within about 1%.

$$\alpha(degrees) = 93.8R_{2f} \tag{7}$$

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